Before The
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In The Matter Of	)	
	)	CC Docket No. 94-102
Revision of the Commission's	)	
Rules to Ensure Compatibility with	)	
Enhanced 911 Emergency Calling Systems	)	
	)	

To: The Commission

COMMENTS OF QUALCOMM INCORPORATED
IN SUPPORT OF PETITION FOR
RECONSIDERATION OF VOICESTREAM WAIVER

QUALCOMM Incorporated ("QUALCOMM") supports the petition for reconsideration filed by the Association of Public-Safety Communications Officials-International, Inc. ("APCO") of the Commission's grant of a waiver to VoiceStream Wireless ("VoiceStream") from the wireless E9-1-1 rules, §20.18 et seq., rules which are applicable to all other wireless carriers, in the Fourth Memorandum Opinion and Order, FCC 00-326, rel. Sept. 8, 2000 ("Fourth MO&O"). QUALCOMM hereby submits the following comments in support of APCO's petition.

I. Introduction

The Commission should reverse its grant of a waiver to VoiceStream because fundamental fairness dictates that the Commission maintain a level playing field for all wireless carriers (and thus all of their respective equipment suppliers) by enforcing one set of E9-1-1 rules applicable to all carriers, irrespective of whether a particular carrier happens to use the GSM, CDMA, TDMA, or iDEN air interface. The public should not have to rely upon different levels of accuracy for E9-1-1 service depending upon which air interface happens to be used by a particular carrier. The public's need for safe E9-1-1 service does not differ based on which air interface a carrier uses. By creating a special exception to the E9-1-1 rules for VoiceStream because it is a GSM carrier, the Commission is, in effect, discriminating against CDMA, TDMA, and iDEN carriers, who will have to comply with more stringent E9-1-1 rules, possibly at a distinctly higher cost. The Commission should not be favoring or disfavoring air interfaces, especially not through a waiver process that is not subject to public comment. All carriers, no matter which air interface they use, should be subject to the same set of accuracy rules.

Further, in addition to the information and other arguments set forth in QUALCOMM's ex parte filings dated September 1 and 7, 2000, which were filed after the adoption of the Fourth MO&O and which QUALCOMM incorporates herein, QUALCOMM submits herewith a July 2, 1999 Technical Report on GSM Mobile Location Systems prepared by eight experts with Omnipoint Technologies, Inc., formerly a subsidiary of VoiceStream.[1] The Omnipoint Technologies Technical Report undermines the grounds on which the Commission granted a waiver to VoiceStream. The Omnipoint Technologies Technical Report shows both that there are compliant technologies available to VoiceStream and other GSM carriers, including uplink TOA (time of arrival)[2], and that the technology that VoiceStream proposes to use, E-OTD (enhanced observed time differences), is not robust, will not produce the level of accuracy

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[1]The Technical Report was prepared to compare and contrast the network architectures of location services and location methods "currently under consideration by the GSM community" (Ex. 1 at Pg. 4) and was made available to a sub-working group under assignment from ETSI considering the standardization of uplink TOA and E-OTD. The Report's authors are: William Lindsey, Murat Bilgic, Gregg Davis, Brian Fox, Ryan Jensen, Tim Lunn, Michael McDonald, and Wei-Chung Peng.

[2]QUALCOMM's September 1, 2000 filing discussed uplink TOA, which was the first automatic location identification technology standardized for GSM carriers.

promised by VoiceStream, and is inferior to uplink TOA, which the Report finds to be very similar to E-OTD but not subject to the same technical problems.

In QUALCOMM's September 1, 2000 ex parte filing, QUALCOMM showed that the test data filed by VoiceStream related to E-OTD was very limited, was from tests conducted only in the most optimal circumstances, and did not comply with the Office of Engineering and Technology's guidelines for such testing.

The Omnipoint Technologies Technical Report addresses many of the questions raised by VoiceStream's limited test data; the Technical Report shows that E-OTD is not robust and is inferior to a technology which does comply with the FCC's rules and which is available to GSM carriers, uplink TOA. For example, the Technical Report finds that users and public safety entities relying on an E-OTD system will suffer location errors due to noise, interference, and multipath problems and proximity to repeaters. Ex. 1 at Pg. 20. Noisy RTD timing measurements alone will result in an up to 40% increase in overall location errors in an E-OTD system as compared to an uplink TOA system. Id. There may not be any solution for the problems stemming from operation near a repeater. Id. at Pg. 22. The Technical Report finds generally that uplink TOA is substantially similar to E-OTD, but E-OTD produces inferior and less reliable results.

The findings in the Omnipoint Technologies Technical Report make it impossible to for the Commission to conclude that there will be substantial public safety benefits from the use of E-OTD, especially when compared to the benefits that would accrue from the use of a compliant technology such as uplink TOA or wireless assisted GPS. The Commission should not waive its accuracy rules to allow VoiceStream to implement a technology with so many technical problems and based upon such an insufficient showing of reliability.[3]

II. **The Commission Should Reverse the Grant of a Waiver to VoiceStream**

The Commission granted a waiver to VoiceStream on two grounds, namely that "(i)t appears that the NSS/E-OTD approach may be the only method available for GSM carriers for compliance with Phase II for some time," and that "VoiceStream's proposed system will provide meaningful public safety benefits. . ." Fourth MO&O at ¶¶ 56, 2. The record of this proceeding, including the Omnipoint Technologies Technical Report, does not support either conclusion.

First, with regard to the availability of location solutions for GSM carriers, the Omnipoint Technologies Technical Report states that there are a "wide variety" of location solutions currently available to GSM carriers. See Ex. 1. at Pg. 4. In particular, QUALCOMM's September 1, 2000 ex parte filing discussed uplink TOA (time of arrival), which was the first automatic location technology standardized by ETSI for GSM carriers and which is being marketed by Omnipoint Technologies. The Technical Report treats uplink TOA and E-OTD (enhanced observed time differences) as alternative "technology choices" and presents study results yielding a detailed technical comparison of the two technologies. Id. at Pg. 4.

The Commission should reconsider the grant of a waiver to VoiceStream because uplink TOA is a compliant alternative available to GSM carriers. The Fourth MO&O does not consider uplink TOA. On this basis alone, the Commission should reconsider that ruling. Indeed,

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[3]To the extent that the Commission predicated the waiver on the so-called NSS safety net promised by VoiceStream, APCO and the International Association of Police Chiefs have stated that "public safety responders ... will receive little, if any, benefit from this offering." APCO Petition at Pg. 6; Letter from International Association of Chiefs of Police, September 1, 2000.

VoiceStream made no showing as to the unavailability of uplink TOA; since VoiceStream owned Omnipoint Technologies until last summer and since VoiceStream has an alliance with the current owner of Omnipoint Technologies, no such showing could be made. VoiceStream, for its own reasons, decided not to adopt uplink TOA, apparently because of the higher cost of installing uplink TOA, but that is no basis upon which the Commission can or should grant a waiver to VoiceStream.

Indeed, the record in this proceeding now shows that there is another compliant alternative for GSM carriers: Allen Telecom's Geometrix network solution. In Allen Telecom's September 15, 2000 ex parte filing, Allen Telecom states that its system "can be adapted to also support the GSM air interface if GSM carriers express interest." See Letter from Eliot J. Greenwald, counsel for Allen Telecom, September 15, 2000 at Pg. 2. The existence of this compliant alternative is another reason why the Commission has to reconsider and reverse its grant of a waiver to VoiceStream.

Second, with regard to the "meaningful public safety benefits" from VoiceStream's proposed NSS/E-OTD system, the Omnipoint Technologies Technical Report compares E-OTD with uplink TOA. The Omnipoint Technologies Technical Report casts substantial doubt about the performance and robustness of an E-OTD system, so much so that the Commission cannot rely on bare promises and insufficient testing by VoiceStream as to the level of accuracy such a system will produce across VoiceStream's nationwide service area. In QUALCOMM's September 1, 2000 ex parte filing, QUALCOMM showed that VoiceStream's testing of E-OTD was clearly insufficient to draw any valid conclusion about the performance of E-OTD on a nationwide basis, was purposely selected to avoid presenting the performance of E-OTD in anything but the most ideal conditions, reflected no attempt to comply with OET's guidelines for such testing, and, thus, was not close to a sufficient basis to grant a waiver to VoiceStream. See September 1, 2000 Ex Parte Letter at Pgs. 5-6.

The Omnipoint Technologies Technical Report, which considers tests of E-OTD conducted in 1998 by Motorola and Nokia and a variety of other sources, shows that the technical problems with E-OTD are extensive, only making the paucity of data from VoiceStream even more telling. There is now no basis for the Commission to conclude that there will be substantial public safety benefits from VoiceStream's use of E-OTD.[4]

The Omnipoint Technologies Technical Report finds that while E-OTD and uplink TOA are very similar in that both are fundamentally time-difference-of-arrival radiolocation systems (the study terms the two technologies "uplink/downlink duals of one another"), E-OTD suffers from the following technical problems: 1) there are more potential sources of error in E-OTD than uplink TOA; 2) noise, interference, and mutipath similar to the OTD measurement degrade RTD timing measurements in an E-OTD system; 3) noisy RTD timing measurements constitute a significant additional source of error in the E-OTD method not present in uplink TOA, such that E-OTD will produce an up to 40% increase in overall location error; 4) uplink TOA is more effectively able to reduce noise and interference through correlation and burst averaging than E-OTD; 5) uplink TOA can benefit from frequency hopping to improve performance in multipath environments while E-OTD cannot; and, 6) an E-OTD system will have difficulty locating a

[4]At minimum, before the Commission can grant a waiver to VoiceStream, VoiceStream should be required to conduct and file more exhaustive testing which reflects OET's guidelines, and which should be analyzed by OET and subject to public comment.

receiver in or near the coverage area of a radio repeater, and there is no simple solution to this problem. Ex.1 at 16, 20, 18, 19, 22, 15.

The Commission must reconsider its grant of a waiver to VoiceStream in the face of these technical conclusions, which undermine the unsupported claims by VoiceStream in this proceeding. The Commission cannot now rely on VoiceStream's scant, highly selective test data because there is now a comprehensive, documented analysis of the E-OTD technology on the record which shows that the technology is not robust and that there are several alternative technologies available which do comply with the Commission's rules. Under these circumstances, the Commission cannot lawfully grant a waiver to VoiceStream.

III. The Commission Cannot Legally Grant A Waiver to VoiceStream

The Fourth MO&O states that while QUALCOMM argued that the Commission is without legal authority to grant a waiver to VoiceStream because it did not file a formal waiver petition, the Commission rejected that argument because the Commission has discretion to grant waivers on its own motion. Fourth MO&O at n.104. The Fourth MO&O misconstrues QUALCOMM's argument, but its conclusion is erroneous in any event. In the Fourth MO&O, the Commission did not grant a waiver to VoiceStream on its own motion. Rather, the Commission "construe(d) the representations (VoiceStream) has made in its ex parte comments to constitute"a waiver request. Fourth MO&O at ¶55. The Commission granted VoiceStream's waiver request. Id. at ¶60 ("Accordingly, we will grant VoiceStream's request for waiver. . ."). See also Separate Statement of Chairman William E. Kennard ("We considered three requests for a waiver. . . Of the three requests, we deny two requests... but grant a limited waiver of our accuracy requirements for VoiceStream.").

The Commission's authority to grant waivers on its own motion does not permit it to grant a party's waiver request, such as VoiceStream's, when the party fails to make the showings required by law to obtain a waiver. Otherwise, the Commission need not ever comply with the law governing its consideration of waiver requests, such as Northeast Cellular Telephone Company, L.P. v. FCC, 897 F.2d 1164 (D.C. Cir. 1990) and WAIT Radio v. FCC, 418 F.2d 1153, 1157 (D.C. Cir. 1969), because the Commission could just grant any defective waiver request by declaring that it was doing so on its own motion. This reasoning cannot stand; the Commission cannot grant a legally defective waiver request for VoiceStream by claiming in a footnote that it was doing so on its own motion, but stating in the text that it was granting VoiceStream's request. Compare Fourth MO&O at n.104 with id. at ¶60.

As QUALCOMM argued in its August 22, 2000 ex parte filing, the Commission should deny a waiver to VoiceStream because while VoiceStream sought a waiver through ex parte discussions, VoiceStream failed to make the showings required by law to obtain a waiver.

The Commission is legally permitted to grant a waiver only upon an appropriate general standard, and the Commission must articulate the nature of the special circumstances facing the proponent of the waiver to prevent discriminatory approaches and to put future parties on notice. Northeast Cellular Telephone Company, L.P. v. FCC, supra. The Commission cannot grant a waiver where the record reveals nothing unique about the situation faced by the party seeking the waiver. Id. at 1166. VoiceStream has not shown anything unique about its situation.

Moreover, "(i)t is well established that the burden is on a waiver applicant to 'plead with particularity the facts and circumstances which warrant'" a waiver. Saddleback Community College, 11 FCC Rcd 11938, 11941 (1996), quoting WAIT Radio v. FCC, 418 F.2d at 1157.

The applicant "must articulate a specific pleading, and adduce concrete support, preferably documentary." WAIT Radio, 418 F.2d at 1157 n.9. A wireless carrier seeking a waiver must show that the underlying purpose of the rule(s) would not be served or would be frustrated by application to the instant case, and that a grant of the requested waiver would be in the public interest; or in view of unique or unusual factual circumstances of the instant case application of the rule(s) would be inequitable, unduly burdensome or contrary to the public interest, or the applicant has no reasonable alternative. 47 C.F.R. §1.925(b)(3). See also Omnipoint Request for Broadband Declaratory Ruling or Waiver, DA 00-1767, rel. Aug. 4, 2000 (WTB). Requests for waiver contain a complete explanation as to why the waiver is desired. 47 C.F.R. §1.925 (b)(2).

There is no exception to these legal standards just because the Commission can grant waivers on its own motion. When a party, such as VoiceStream, comes to the Commission and seeks a waiver, it must meet these standards. VoiceStream has not done so and cannot do so.

IV. Conclusion

Wherefore, for the foregoing reasons, QUALCOMM respectfully requests that the Commission reconsider and reverse the grant of a waiver to VoiceStream.

Respectfully submitted,

By:____________________

Dean R. Brenner
CRISPIN & BRENNER, P.L.L.C.
1156 15th Street, N.W., Suite 1105
Washington, D.C. 20005
(202) 828-0155

Attorneys for QUALCOMM Incorporated

ANDREWS OFFICE PRODUCTS CAPITOL HEIGHTS, MD (K)

Exhibit 1

GSM Mobile Location Systems

Omnipoint Technologies, Inc.

Authors:

William Lindsey, Murat Bilgic, Gregg Davis, Brian Fox, Ryan Jensen, Tim Lunn, Michael McDonald, Wei-Chung Peng

July 2, 1999

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1 Introduction

Under FCC rules, by 1 October 2001 U.S. wireless operators must implement the capability to locate E911 callers with a RMS accuracy of 125 meters. Many operators also plan to support other location-based services commonly referred to as location-based value added services (VAS).

In the context of mobile communications, location systems have been under research and development for a number of years world wide. Coupled with the unprecedented development of mobile communications, the mobile communications community and the standards organizations have been actively considering how location system technologies can enable the cost-effective provisioning of location-based VAS. A wide variety of location solutions, both terrestrial and satellite-based, are currently available and other solutions are expected to be developed.

The purpose of this technical report is to compare and contrast LCS network architectures[1]and location methods currently under consideration by the GSM community. The location methods under consideration herein include network based Uplink Time of Arrival (UL-TOA) and handset based Enhanced Observed Time Difference (E-OTD). At present, these technology choices are being standardized for the global GSM community in the context of both ETSI and ANSI standards.

The T1P1.5 LCS sub-working group (SWG), under assignment from ETSI with the support of the ANSI accredited committee T1, is developing the relevant GSM LCS standards. Participant companies in this standardization process have expounded various contradictory claims regarding the strengths and weaknesses of the prospective technologies.

The study results presented in this report compare the relative merits of UL-TOA and E-OTD in detail. The support of A-GPS is also discussed to a lesser extent. The comparison is made from both a technical as well as a business perspective. The presentation is made in such a way that the issues associated with the technology choices become clarified.

2 Operator Issues for Location Services

2.1 FCC E911 Mandate for the Support of Emergency Services

It is clear that meeting the FCC 125 meter RMS accuracy requirement for all E911 calls in the face of the technical issues examined in Section 5 will be very challenging, whichever LCS solution is employed.

While no equivalent emergency services mandates to the FCC's E911 requirement currently exist outside of the United States it is now apparent that some regions of the world are becoming increasingly interested in this type of emergency services provision.

- **US operators should carefully consider the ability of the alternative solutions to meet the FCC requirements.**

- **Global interest is growing for location support of emergency services.**

[1] An *architecture* is the arrangement and interconnection of system components. In contrast, a location *method* is the way in which location measurements are undertaken, i.e. UL-TOA, E-OTD or A-GPS.

2.2 Commercial and Operator Services Requirements

The likely popularity of different identified and as yet unidentified commercial location services can have a major impact on the location technology choice because different applications place quite different requirements on the location technology attributes that must be provided. Some critical attributes can be identified as follows:

- Location determination performance (accuracy and latency)
- Impact to existing wireless system resources and equipment for normal call processing
- Support for rapid location updating
- Support for privacy
- Support for legacy handsets
- Support for autonomous handset based location determination

The alternative location methods and alternative LCS network architectures have varying levels of support for these, and other attributes. As a result, the selection of a preferred LCS solution is dependent upon judgements about the success and priority that should be afforded to different LCS applications. To date, no consensus has been reached by interested parties regarding these judgements and priorities.

- ♦ **Operators should deploy a general, flexible architecture to support LCS as specific application requirements are not yet fully determined.**

2.3 FCC Waivers

The willingness of the FCC to grant "waivers" for handset based LCS solutions, essentially allowing legacy handsets not to be supported with LCS provision, remains an open question. The FCC recommended that all such waiver requests be filed by February 4, 1999 and indicated guidelines for information disclosure whereby such requests might be seriously considered.

More than 50 related submissions have been filed with the FCC on this topic to date. The submissions comprise a combination of waiver requests, comments and oppositions. In general, it is clear most of the submissions are:

1. Requesting more time to review LCS technology solutions
2. Requesting a waiver to allow the option of a handset based solution - if that is feasible
3. Requesting relief in terms of a phased-in approach for the FCC Phase 2 requirement

While the FCC has still not taken any decision on granting waiver requests, they have reiterated their position that the compliance date will not be delayed and have encouraged not only meeting the date but also beating the date. It has also become clear that some operators who have requested a waiver believe they will be granted one, providing they agree to undertake some form of handset swap out program.

- ♦ **The conditions under which the FCC will grant waivers, if at all, have yet to be resolved.**

2.4 Legal Liability

One fundamental aspect of the liability associated with E911 provision is concerned with users who make tort claims based upon the inability to be located with sufficient accuracy (or at all) to mitigate their emergency situation. To be found liable for negligence, an operator must be shown to have violated some recognized standard of care, and to have actually caused damages. Approaches that cannot support legacy or roamer handsets may have greater exposure to liability. Approaches that are inherently less accurate than others may also suffer from negligence claims related to adopting a "less safe" solution. These risks are highest if the solution fails to comply with FCC rules and has few obvious safety advantages compared to alternative approaches.

Currently, there is no Federal immunity for operators providing E911 service that might preempt state tort laws. However, the House of Representatives recently passed HR 438, the 'Wireless Communications and Public Safety Act of 1999', which among other items grants liability protection equal to the protection given to wireline carriers. The Senate is now considering their own version of this bill. Additionally, approximately thirty states have granted wireless operators differing levels of state immunity from suit for acts related to the provision of E911 service. However, the twenty or so remaining states, including New York and California, have no such protection.

Where there is no state liability protection related to the provision of E911 service the operator's only recourse is to include contractual disclaimers in their agreements with customers or in their published tariff disclosures. As a result of the inherent liability risks, pending further legislative action, it is likely that operators will purchase liability insurance to mitigate the threat of significant financial losses arising from successful tort claims. It remains an area of uncertainty and industry debate whether these liability insurance costs can reasonably be included as costs to be recovered as part of some as yet to be defined cost recovery mechanism for wireless E911 provision.

- **Operators should deploy location solutions that afford them maximum protection from liability risks.**

2.5 Privacy

In general, the technical provision of LCS allows the target MS being positioned to restrict access to the ability to locate it both permanently and on a per attempt basis. This facility is enabled by the utilization of a "MS LCS subscription profile" which indicates whether or not specific authorization for location determination is allowed by external entities requesting location of the target MS.

Location services can be divided into four classes:

1. Emergency services (including E911)
2. Lawful interception
3. Wireless operator specific location (anonymous mode)
4. VAS

In the case of service classes 1, 2 and possibly 3, any target MS can be located irrespective of the status in the MS LCS subscription profile. In these cases no indication need be given to the user of the target MS that a location operation is being undertaken. In the case of service class 4, access to the location capability shall be undertaken according to the subscription profile. In this case, it seems likely that a notification shall be given to the user that a location operation is being undertaken.

It is potentially an area of concern for UL-TOA operation to provide a relevant indication to a legacy handset that a positioning operation under class 4 above is being undertaken so that the users' privacy is not compromised.

- **The privacy perception issue for legacy handsets cannot be resolved until further definition is given on the privacy requirements.**

2.6 Infrastructure and Handset Complexity

Providing technical and regulatory requirements can be met, complexity will be one of the critical determinants in the selection of the alternative technical solutions available. Certainly, in the case of commercial LCS provision, the infrastructure and handset costs will need to be weighed carefully against the revenue streams that can be expected to flow.

One mitigating factor for covering the costs associated with deploying the required infrastructure to support LCS will be the magnitude and extent to which a cost recovery mechanism for emergency services provision exists. This remains an area of uncertainty and specific proposals for applicable cost recovery mechanisms remain lacking.

- **The magnitude and extent of possible E911 cost recovery mechanisms are not yet clear.**

2.7 Deployment

One major concern with the provision of LCS is the deployment of the additional network infrastructure associated with E-OTD and UL-TOA implementation. Both E-OTD and UL-TOA require the installation of additional Location Measurement Unit (LMU) equipment (either integrated with a BTS or not) to enable location determination to be undertaken. Integration of the LMU[2] with the BTS provides some advantages for deployment. However, legacy BTS equipment has not, in general, been designed with this integration of LCS equipment in mind. As a result, it is not practical for the majority of installed GSM systems to integrate the LMU with the BTS. It follows that an air interface link between the BTS and the LMU provides an open, flexible interface.

The ability to locate the UL-TOA LMUs away from the BTS offers advantages for corridor deployments, coverage, zoning, GPS visibility, etc. E-OTD LMUs can also be remotely located, but there are few advantages in doing so.

- **An external LMU is unavoidable for the majority of deployed GSM systems. Use of a standard GSM air interface provides an existing, open and flexible LMU-BTS interface.**

- **An LMU-BTS air interface provides valuable flexibility for deployment.**

2.8 GSM Evolution

The LCS solution developed for circuit switched GSM telephony usage prevalent today should also be consistent with the evolution of GSM to higher speed packet data applications. In particular, the advent of General Packet Radio Service (GPRS) and IMT2000 (otherwise loosely referred to as UMTS or WCDMA) poses some questions for how LCS solutions will interoperate with these new wireless access schemes.

It seems likely that A-GPS technology will play an important role for LCS needs in these next generation wireless access systems as cost, complexity and integration issues are mitigated. It is not yet clear the extent to which UL-TOA or E-OTD could or should be incorporated into the new systems. One important consideration is the extent to which these new wireless access technologies will be dependent upon existing GSM for ubiquity of service coverage. If that is true and the vast majority of third generation terminals have dual mode capability with second generation GSM functionality, then utilizing the second generation LCS solutions (E-OTD or UL-TOA) seems a likely and desirable approach.

- **The possible uses of second-generation LCS solutions and A-GPS to support third-generation systems have not yet been defined.**

3 LCS System Architectures

An alternate proposal for a combined NSS and BSS based architecture for LCS has recently been proposed by Siemens [17]. This proposal essentially allows the operator to place the SMLC either in the BSS

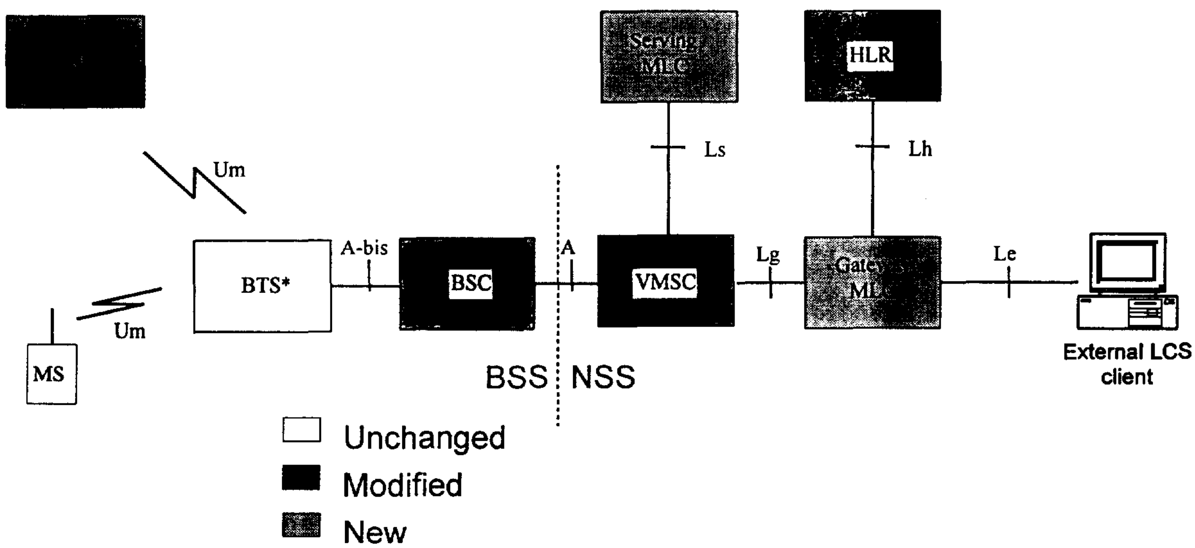
[2] An UL-TOA LMU measures the time of arrival of MS transmissions; an E-OTD LMU measures the relative time difference between BTS transmissions.

(connected via the BSC) or the NSS (connected via the MSC). Currently, the T1P1.5 LCS sub-working group is considering pursuing this proposed architecture for the second phase of LCS standardization, while the NSS based architecture will continue to be standardized for the first phase. Because there are still significant details of this proposal left undefined, this proposed combined architecture is not addressed in this report.

3.1 NSS-Centric Architecture

The architecture is termed NSS-centric because a significant portion of the LCS functionality resides in the NSS. As shown Figure 1, new NSS components, GMLC and SMLC, are added for LCS. The new NSS components are connected to the existing NSS components, i.e. VMSC and HLR, via SS7-based interfaces. The GSM network is connected to the external non-GSM networks via a non-GSM interface called Le. Over the Le interface, clients within the external networks can request positioning information for specific mobile stations.

The NSS-Centric Architecture specifies the use of stand-alone LMUs that communicate with the SMLC in the NSS. LMUs communicate with the SMLC over standard GSM interfaces, using MAP and DTAP signaling. Alternatively, an LMU can be designed as part of the BTS.



*LMU-BTS interface other than Um implies BTS changes

Figure 1: LCS NSS-Centric Architecture

In the E-OTD and A-GPS location methods, the position calculation may reside in the MS but, alternatively, may be placed in the NSS, i.e. the SMLC. In the A-GPS method the position calculation is likely to be in the MS. However, for both of these methods, the positioning coordination would be kept in the SMLC.

- **In the NSS architecture the new components, LMU, SMLC and GMLC, use open interfaces.**

Both the E-OTD and the A-GPS positioning methods are based upon the principle of adding LCS functionality into the MS. In the case of E-OTD, this functionality is at least the time delay measurement capability. Optionally, the MS may perform the positioning calculation as well. In the case of A-GPS, the MS performs both measurement and positioning calculation. Because of these significant changes in the MS capability, some changes to the NSS-Centric Architecture are also necessary.

Information necessary for the E-OTD positioning calculation includes cell site geographical coordinates, BCCH frequency, BSIC and identities of the cells, the time slot lengths for each cell and the relative time difference (RTD) between CCCH transmissions for each cell pair.

Both the E-OTD and A-GPS location methods require the dissemination of this LCS assistance information from the network to the MS when handset-based position calculation is to be performed in the MS. The most suitable method may be to provide this information in a broadcast fashion controlled by the BSS, requiring changes to the current NSS-Centric Architecture.

- **The NSS-Centric Architecture has been defined by the T1P1.5 LCS SWG and can support both network and handset-based methods.**

3.2 BSS-Centric Architecture

In contrast to the NSS-Centric Architecture, an alternative BSS-centric architecture can be envisaged [2, 3]. This can be termed BSS-centric since, apart from the functionality in the GMLC, almost all the LCS functionality resides in the BSS.

If the LMUs are integrated with the BSS, then the BSS-centric architecture can use interfaces within the BSS to transfer the measurement information from the LMUs to the unit where the position calculation is performed. However, in the likely event that the LMU cannot be integrated with the existing BSS equipment and it has to use the Um interface to communicate with the SMLC in the BSS, then new approaches have to be devised. One alternative is to use a new layer 3 protocol whose messages can be carried between an MLC within the BSS and the LMU over the RR protocol. To distinguish this new protocol from DTAP, a new protocol discriminator will be required. In addition, the MLC within the BSS has to perform the subscriber management functions for the LMU which would be provided by the VMSC in the NSS-centric architecture. This may include authentication, identity check and profile management for LMUs. Another alternative is to have less drastic changes, by keeping the subscriber management functionality for the LMUs within the NSS, but augmenting the RR protocol with new LCS specific functionality.

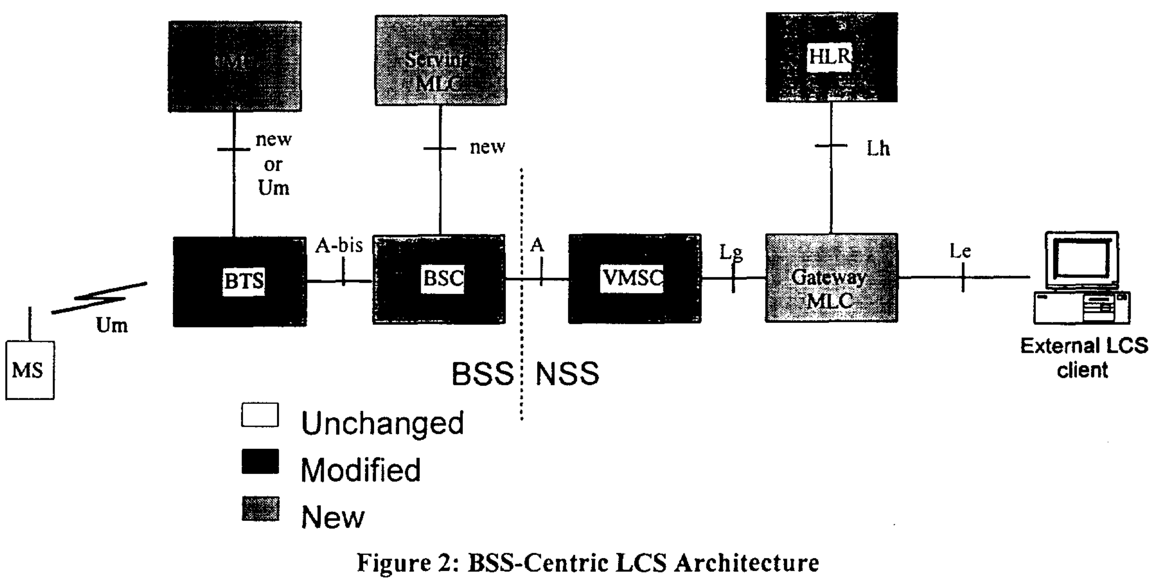


Figure 2: BSS-Centric LCS Architecture

- **The BSS-centric architecture implies the development of significant new BSS functionality.**

- **The development of new interfaces in the BSS-centric architecture increases implementation risk.**

- **The BSS-centric architecture is still relatively immature with important details, such as support for UL-TOA, not yet described**

4 Comparison of the Architectures and Methods

This section compares the operation and performance of the NSS-centric and BSS-centric architectures and the UL-TOA and E-OTD location methods in the critical areas of impact on existing network elements, capacity, LMU functionality, operation with repeaters and evolution to third-generation systems.

4.1 Impact on Existing Network Elements

The impact of implementing LCS on deployed PLMN equipment has two components:

- risks and complexity associated with incorporating new LCS equipment (including the MS)
- risks and complexity associated with upgrading or modifying existing GSM equipment

THE CHANGES ASSOCIATED WITH THE IMPLEMENTATION OF LCS FOR THE NSS-CENTRIC AND BSS-CENTRIC ARCHITECTURES ARE SUMMARIZED IN TABLE 1.

Table 1: Impact of LCS Functionality on Existing Network Elements*

Method	Network Element	NSS-Centric Architecture (with LMU-BTS air interface)	BSS-Centric Architecture (with LMU-BTS wired interface)
UL-TOA	MS	None	None
	BTS	None	H/W and S/W interface/integration with LMU.
	BSC	S/W update for new BSSMAP messages.	H/W and S/W interface/integration with MLC. S/W for new BSSMAP messages.
	VMSC	Interface to SMLC and GMLC. New LCS S/W component.	Interface to GMLC. New LCS S/W component.
	HLR	Privacy profile information. LMU information.	Privacy profile information.
E-OTD	MS	S/W update to perform E-OTD measurements and signaling. Possible H/W update to support additional processing.	S/W update to perform E-OTD measurements and signaling. Possible H/W update to support additional processing.
	BTS	None	H/W and S/W interface/integration with LMU.
	BSC	S/W update for new BSSMAP messages.	H/W and S/W interface/integration with MLC. S/W for new BSSMAP messages.
	VMSC	Interface to SMLC and GMLC. New LCS S/W component.	Interface to GMLC. New LCS S/W component.
	HLR	Privacy profile information. LMU information.	Privacy profile information.

*This table only treats specific proposals that have been covered by T1P1.5 to date—other interface implementations are possible but have not been treated because their definition is incomplete at this time.

It is clear that only the UL-TOA positioning method allows owners of legacy mobiles to use LCS services; the mobiles of users of a network with an E-OTD positioning method require the MS software to perform the location measurements and signaling.

The NSS-centric architecture has the advantage of minimizing the number of network elements affected by the addition of LCS. In particular, the absence of changes to the BTS avoids the significant risk associated with modifications to the large number of such remotely located units. Another potential advantage of the NSS-centric architecture, particularly for operators with multiple vendors, is that the BSC requires only a SW upgrade as opposed to HW and SW.

- **A combination of NSS-centric architecture with the UL-TOA location method requires the least modification of current infrastructure for operators with deployed equipment.**

4.2 A-Interface Capacity Requirements

Regardless of positioning method, two fundamental operations directly affect traffic routing through the network. These are:

- Positioning Radio Coordination Function (PRCF)
- Positioning Calculation Function (PCF)

Both of these operations can be performed in either the NSS or the BSS. The primary interface that is affected by this difference, in terms of traffic, is the A-interface.

The measurement Request/Response and RIT messages are the most significant contributors to traffic over the A-interface. There are more Request/Response messages in UL-TOA than E-OTD, since communication is with several UL-TOA LMUs. RIT messages are more common for E-OTD, since measurements are received from several E-OTD LMUs.

If the PRCF is performed in the NSS, Request messages traverse the A-interface. If the PRCF is performed in the BSS, only Request messages to the adjacent BSC area go over the A-interface.

Likewise, if the PCF is performed in the NSS, Response messages and RIT messages traverse the A-interface. If the PCF is performed in the BSS, only Response messages and RIT messages from adjacent BSC areas come over the A-interface.

Following the approach taken in [4, 15], signaling traffic on the A-interface can be calculated from the equation

$$N_{SS7links} = \frac{\frac{N_{source} \cdot N_{report} \cdot P}{N_{same}}\left(N_{message} + N_{MTP} + N_{SCCP} + N_{TCAP/MAP}\right) \cdot 8}{64,000 \cdot T}$$

where:

$N_{SS7\,links}$ is the number of SS7 links required

N_{source} is the number of source elements (either subscribers or LMUs)

N_{report} is the number of LMUs involved

P is the portion of overlap

N_{same} is the number of LMUs that can be contained in one BSSMAP message

$N_{message}$ is the number of bytes in the message

N_{MTP} is the number of MTP overhead bytes

N_{SCCP} is the number of SCCP overhead bytes

$N_{TCAP/MAP}$ is the number of TCAP/MAP overhead bytes

T is the update periodicity.

For this analysis, the assumptions listed in Table 2 apply:

Table 2: Capacity Analysis Assumptions

Item	Message/Method	Value
N_{source}	Request/Response RIT	1 subscriber [4] 3,000 LMUs [15]
N_{report}	TOA E-OTD	7 [4] 2 [4]
P	TOA E-OTD	15% 30% [15]
N_{same}		15 LMUs [15]
$N_{message}$	Request/Response (NSS) Request/Response (BSS) RIT (NSS) RIT (BSS)	36 bytes (for one subscriber using DTAP) [4] 57 bytes (for 15 subscribers using BSSMAP) 97 bytes (for one LMU using DTAP) [15] 155 bytes (for 15 LMUs using BSSMAP) [15]
N_{MTP}		15 bytes [4]
N_{SCCP}		12 bytes [4]
$N_{TCAP/MAP}$		40 bytes [4]
T	RIT	30 seconds [15]

Recent trends [16] show that there is an average of 0.0015 E911 calls per subscriber per day. If calls are made during 12 busy hours then the call arrival rate per 100,000 subscribers is around 1 every 300 s. Hence, for E911 calls alone the request/response traffic generated is shown in Table 3.

Table 3: Comparison of E911 Signaling Traffic with PRCF in the NSS or BSS (Number of Required SS7 Links)

Architecture	Message	UL-TOA	E-OTD
NSS	Request	3×10^{-4}	9×10^{-5}
BSS	Request	2×10^{-6}	0

- **For either architecture, E911 does not generate enough traffic to significantly impact capacity.**
- **To begin to impact network signaling, LCS value added services need to generate approximately 1000 times the traffic of E911 LCS operation.**

The traffic generated by RTD information updating every 30s is shown in Table 4.

Table 4: Comparison of Signaling Traffic with PCF in the NSS or BSS (Number of Required SS7 Links)

Architecture	Message	UL-TOA	E-OTD
NSS	RIT	N/A	2.1
BSS	RIT	N/A	0.046

Locating the PCF in the BSS reduces traffic on the A-interface due to the RIT messages.

For high update rates, the RIT signaling may be reduced by supplying RTD information only when a location measurement is made, rather than at a fixed interval.

- **The BSS-centric architecture generates less signaling traffic on the A-interface than the NSS-centric architecture, especially for the E-OTD location method.**

Analysis indicated that UL-TOA measurements by the LMUs can be queued while still meeting the overall requirement for delay in delivering the location solution to the PSAP. Simultaneous UL-TOA measurements are not required at the LMU.

4.3 Impact of Location Method on LMU Functionality

The functionality of the LMU for UL-TOA is contrasted with that of the LMU for E-OTD in Table 5.

Table 5: Comparison of LMU Functionality for the TOA and E-OTD Methods

Function	UL-TOA	E-OTD	Comparison
Antenna interconnection	Single or dual diversity, RF switch for multi-sector	Single or dual diversity	Similar (see note 0)
RF front end	Single or dual for diversity	Single or dual for diversity, with high dynamic range	Similar (see note 2)
Timing measurement	Correlation, averaging and timing extraction	Correlation, averaging and timing extraction	Similar
Clock	Disciplined clock driven by GPS	Stable over measurement interval, implies disciplined clock driven by GPS	Similar (see note 3)
Network interface	Either over-the-air, wired or integrated	Either over-the-air, wired or integrated	Similar (see note 4)
Packaging	Outdoor enclosure, industrial temperature range	Outdoor enclosure, industrial temperature range	Similar

Notes:

1. LMU diversity reception can mitigate bad multipath, giving less chance of skewing the timing estimate. UL-TOA can benefit from some channel decorrelation due to MS motion and frequency hopping, whereas RTD measurements in E-OTD are between stationary radios on channels that do not hop.
2. The LMU for TOA receives the A-bursts in the uplink band; the LMU for E-OTD receives the CCCH bursts in the downlink band. Both LMUs will commonly be co-located with BTS. The TOA receiver can depend on at least 20 MHz separation between the received channels and the transmissions of the nearby BTS; E-OTD cannot depend on this.
3. The UL-TOA LMU clock has a requirement to be stable over a similar interval as the E-OTD LMU clock.
4. Retrofitting of an integrated LMU may not be possible for most deployed GSM BTSs.

The operation of the LMU for a particular positioning method is independent of the supporting network architecture. Furthermore, Table 5 shows that LMU functionality is largely independent of positioning method.

- **The LMUs for UL-TOA and E-OTD have very similar functionality and complexity.**

4.4 Evolution of Architectures to Support GPRS and EDGE

The support of GPRS positioning using the NSS-centric architecture is described in [5]. The approach requires that the SGSN software be upgraded to handle LCS messaging. BTS and MS functionality is not changed.

The support of GPRS positioning using the BSS-centric architecture has not been described in detail yet. However, it is expected that GPRS positioning requests initiated through the SGSN attached to the BSC would be possible to define [4].

EDGE is basically an air interface enhancement to GSM. As such, any network architecture that can handle LCS for GSM and GPRS will be able to perform LCS operations for EDGE.

- **It is expected that both the NSS-centric and BSS-centric architectures will support GPRS and EDGE.**

4.5 Comparison of Evolution to Third-Generation Systems

Since UMTS is significantly different from GSM it is unlikely that 2G network elements will be reused for 3G network functions.

It is a feature of CDMA that neither UL-TOA nor E-OTD positioning methods are particularly suitable, as both require idle slots that will disrupt user data transfer. Of the two, UL-TOA with IS-RL will have a much more serious capacity impact due to its requirement for idle slots for each MS to be positioned.

It is expected that UMTS will not be immediately deployed ubiquitously but will have more of a gradual rollout, so many of the new 3G terminals will be dual-mode GSM/UMTS allowing the second-generation LCS method to be used.

- **Understanding of network evolution to 3G is so immature that no definitive statements are possible at this time.**

- **The second-generation LMUs cannot be reused for a WCDMA system.**

4.6 Evolution to Support A-GPS

Assistance information, allowing faster acquisition from code phase information and better accuracy from differential information, is derived from timing information supplied by a reference GPS receiver.

The NSS-centric and BSS-centric architectures require the signaling of the acquisition assistance and differential information to the BSS for broadcast to MSs. The reference receiver is expensive and only required every 200 km, so locating it at the SMLC is logical for the NSS-centric architecture. Sharing a reference receiver between multiple BSCs is sensible for the BSS-centric architecture, however this will require new BSC-BSC signaling.

- **Support for A-GPS is similar for both NSS-centric and BSS-centric architectures.**